Sea Surface Salinity Distribution in the Southern Ocean as Observed from Space

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Abstract

Large scale spatial and temporal variabilities of sea surface salinity (SSS) in the Southern Ocean from 2011 to 2017 were studied using products derived from Aquarius/SAC-D, Soil Moisture and Ocean Salinity (SMOS), and Soil Moisture Active and Passive (SMAP) satellites. SSS products were generally consistent within 0.3 to 0.6 psu, and agree favorably with in situ data with rmse values from 0.25 to 0.58 psu. Some differences observed are due to retrieval algorithms, smoothing, masking of sea ice, and bias-adjustment. Aquarius products show consistent seasonality of SSS, but not SMOS and SMAP. Our analyses show that SSS in the Southern Ocean region has significant meridional variations with the lowest SSS near the ice edge and highest at lower latitudes. The SSS is also lowest in summer indicating the predominant influence of sea ice and glacial melt, but it stays low near ice edges even during the growth season.

I. Background & Objectives

Monitoring large- and small-scale changes in SSS in the Southern Ocean through satellites offers an unprecedented opportunity to investigate salinity's role in ocean-atmosphere coupling, sea ice dynamics, polar hydrological cycle, biological productivity, and ocean circulation. Since space-borne SSS is still fairly new, challenges still exist due to reduced sensor sensitivity in colder waters, improper detection of sea ice edge location, and the dearth of validation studies in the region.

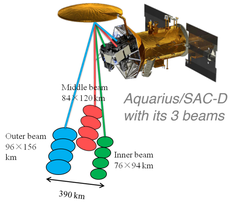
Study aims to:

- Investigate SSS variations in the Southern Ocean using SMOS, Aquarius, and SMAP;
- Provide an assessment of the accuracy of SMOS and Aquarius during years of overlap by comparing it with in situ data from (a) ice-breaker, and (b) point measurements from Coriolis Ocean database for ReAnalysis (CORA) v5.0; and
- Given that salinity continuity is an important focus of NASA, we include a comparison of Aquarius and SMAP seasonal trends and distribution.

II. Data and Methods

Satellite data:

Aquarius is a NASA instrument launched in 10 June 2011. It has 3 L-band radiometers and 1 scatterometer. Revisit time of 7 days and spatial resolution of ~150 km. Aquarius data used here are AqGSFC, AqJPL, and AqNSIDC produced with 12.5 km resolution and running weekly averages. Said products and descriptions are available here: https://neptune.gsfc.nasa.gov/csb/index.php?section=482.



Aquarius/SAC-D with its 3 beams

SMOS and MIRAS instrument

SMOS and its Microwave Imaging Radiometer with Aperture Synthesis (MIRAS) instrument is a European Space Agency (ESA) project launched in 2 November 2009. Revisit time of 3 days and spatial resolution of 35-50 km. SMOS data used here is the Objectively-Analyzed level 3 product of the Barcelona Expert Centre, which is available here: http://cp34-bec.emima.csic.es

SMAP is also a NASA instrument launched in 31 January 2015 primarily for monitoring soil moisture, but also suitable for SSS retrieval. Revisit time is 2-3 days with resolution of 40 km. Just like Aquarius, it also has a scatterometer, which unfortunately failed in 7 July 2015. We used the RSS level 2 v2.0 product from: http://podaac.jpl.nasa.gov

SMAP instrument

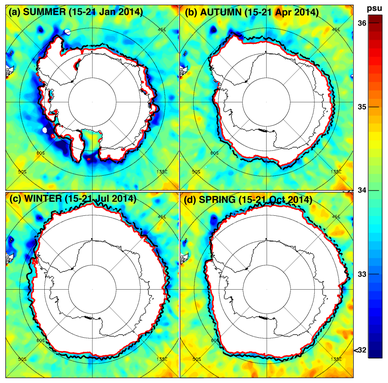
In Situ data:

Polarstern thermosalinograph (TSG) measurements from a few meters of the ocean surface during the summer of 2011 to 2015 were used to validate the space-borne SSS. Data downloaded here: https://www.pangaea.de/expeditions/cr.php/Polarstern.

CORA v5.0 quality-controlled salinity data from the Coriolis database was also used for validation. Data available here: http://www.seanoe.org/data/00351/46219/.

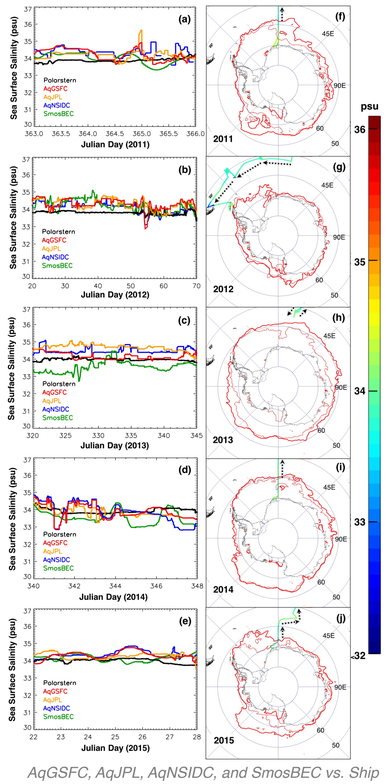
For the collocation of satellite and in situ data, salinity measurements within a 12.5 km x 12.5 km grid cell and within ±3 days are averaged together.

III. Results

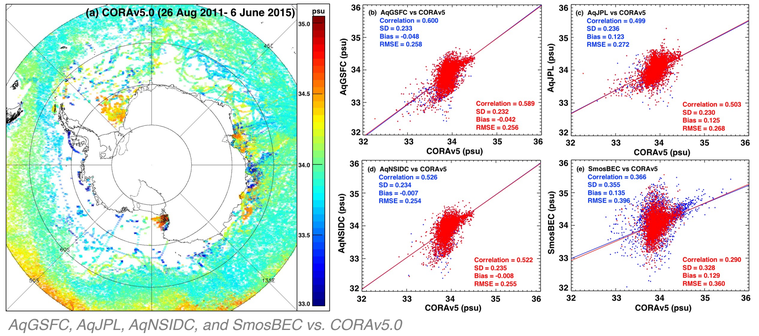


AqGSFC and sea ice edge contours from Aquarius &SSM/I

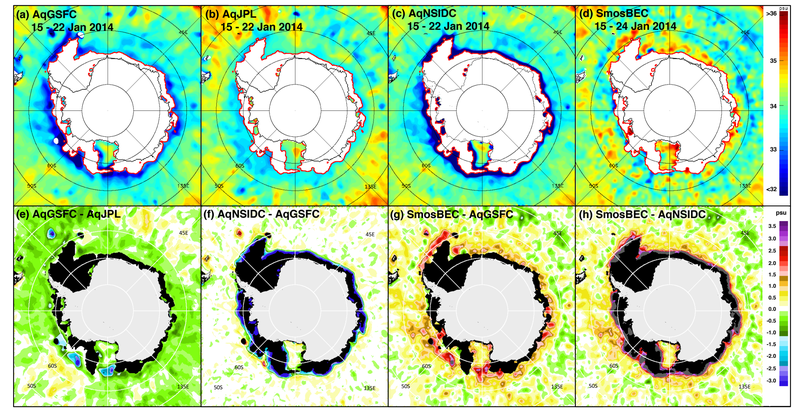
- Sea ice edge inferred from Aquarius (black) and SSM/I (red) showing Aquarius ice fraction extending further northward.
- Satelllite SSS products vs ship: standard values from 0.04-0.30 and rmse values from 0.28-0.58.
- When compared to CORAv5.0, standard values from 0.23-0.33 and rmse values are from 0.25-0.36.



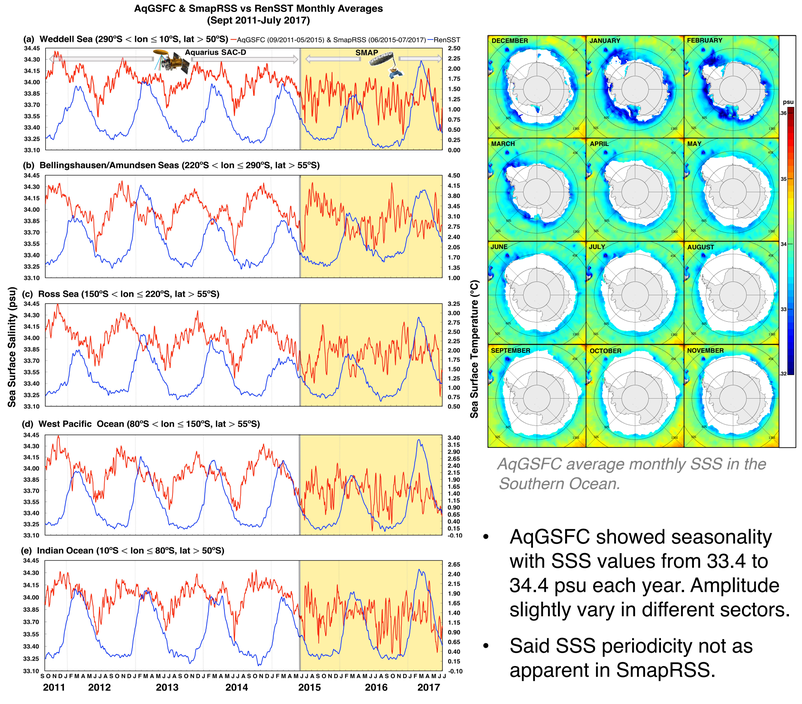
AqGSFC, AqJPL, AqNSIDC, and SmosBEC vs. Ship



AqGSFC, AqJPL, AqNSIDC, and SmosBEC vs. CORAv5.0



AqGSFC, AqJPL, AqNSIDC, & SmosBEC in summer 2014 & difference maps comparing each products.



AqGSFC average monthly SSS in the Southern Ocean.

- AqGSFC showed seasonality with SSS values from 33.4 to 34.4 psu each year. Amplitude slightly vary in different sectors.
- Said SSS periodicity not as apparent in SmapRSS.

IV. Conclusions

- Comparison of 4 SSS products show general consistency but differ because of data processing, sea ice masking, and perhaps due to available concurrent scatterometer.
- Validation of satellite-derived SSS using quality-controlled data from ice-breaker, and CORAv5.0 resulted to rmse values from 0.25 to 0.58.
- Satellite-derived SSS agree with expected seasonal and interannual changes in the Southern Ocean.